MTR-921

MICROPROGRAMMING FACILITY

R. W. Cornelli

NOVEMBER 1969

Prepared for

DIRECTORATE OF PLANNING AND TECHNOLOGY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

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Project 7120
Prepared by
THE MITRE CORPORATION
Bedford, Massachusetts
Contract AF19(628)-5165

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FOREWORD

This report describes the microprogramming facility at The MITRE Corporation, Bedford, Massachusetts. It is in partial fulfillment of Project 7120 under Contract No. F19 628-68-C-0365. It was prepared under the cognizance of Mr. Robert W. Cornelli of The MITRE Corporation. The USAF project monitor is Mr. Russell A. Meier.

REVIEW AND APPROVAL

Publication of this technical report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

WILLIAM F. HEISLER, Colonel, USAF
Chief, Command Systems Division
Directorate of Planning and Technology

ABSTRACT

The microprogramming facility at MITRE is designed to develop and explore the technology in the relatively new field of microprogramming.

This document describes the facility.

ACKNOWLEDGMENT

This document contains contributions from other members of the microprogramming group, notably:

R. G. Curtis

B. J. Huberman

A. D'Agostino

M. M. Mills

J. V. Sullivan

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LIST OF ILLUSTRATIONS

SECTION I

INTRODUCTION

The microprogramming facility at MITRE is designed to develop and explore the technology in the relatively new field of microprogramming (Figure 1). Briefly, a microprogrammed computer is one in which the basic control circuitry performs an extremely primitive set of operations, much more elementary than the instruction sets of conventional machines. By executing sequences of these micro-operations stored in a special, fast memory (a "firmware" program), any desired set of conventional machine instructions can be implemented.

MITRE's microprogramming facility is based on an Interdata 3 computer (the I-3). Using this basic hardware, the I-3 processor, and building microprograms (firmware) and conventional programs (software), some of the impact of microprogramming will be explored.

VENUS, now under construction, is an experiment using the facility. As such, it is an operating system which will explore some of the problems of efficient, effective large program production, using microprogramming to influence the apparent computer architecture. It will be documented elsewhere.

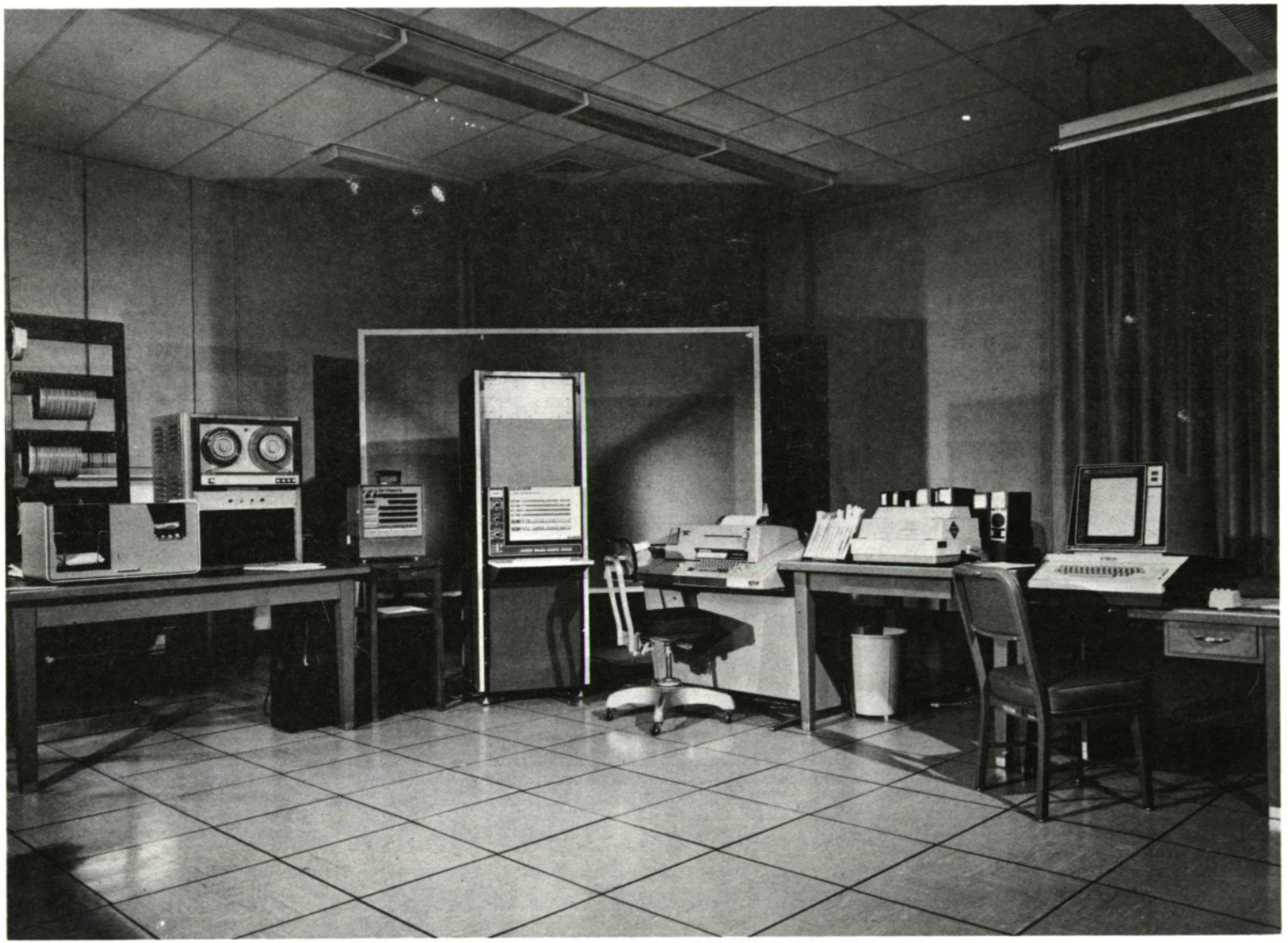

Figure 1. Microprogramming Facility

SECTION II

HARDWARE

GENERAL

The hardware consists of an Interdata 3 central processor, plus a collection of peripheral devices. All of these devices are attached directly to the central processor, except the disc, which is connected to the selector channel.

The following equipment is currently installed:

Device Address (Hex)	Device Name
1	Display Panel
2	Teletype - Model 35 ASR
3	Teletype - Model 33 ASR
4	Soroban Card Reader
5	Kennedy Magnetic Tape
6	Data Disc
7	Selector Channel
8	Clock
9	Not Used
A	ARDS (Advanced Remote Display Station)
C	Reserved for Future Motorola Printer
D	Motorola Printer
E	Teletype - Model 33 ASR

Up to 256 devices, with addresses up to FT (hex) may be attached.

System Test Set

The System Test Set (Figure 2) is an adjunct to the central computer which provides manual control of the I-3 for hardware test and checkout purposes.

Photograph	Figure 2
Reference	Interdata 30-254, System Test Set Operation

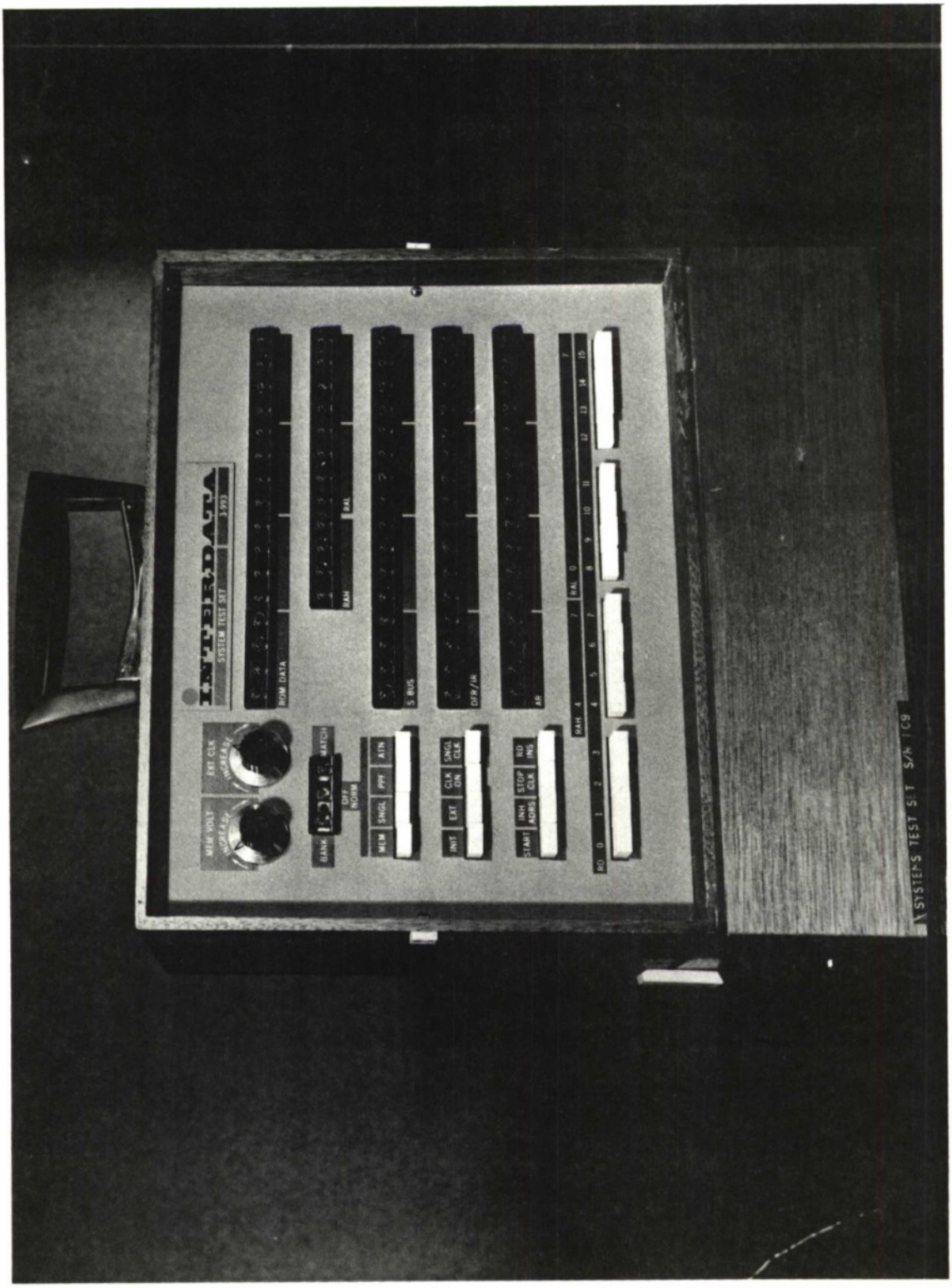

Figure 2. System Test Set

CENTRAL PROCESSOR

Memory		
ROM	Size:	1024 16 bit words each, 2 maximum
	Speed:	370 nsec for 16 bits
Main	Size:	65K 8 bit bytes, byte addressable
	Speed:	1.5 μsec for 16 bits
Size		19" W x 10½" H x 14" D
Weight		100 pounds (includes power supply)
Power		115V $\pm$ 10%, 47 to 63 cps
References		
Brochure		Interdata, Digital Systems, Model 2, Model 3, Model 4
Article		Data Processing Magazine, February 1968, P. J. L. Wallis, Auerbach Info Inc., The Interdata Series
Delivered I-3		Interdata 29-004, Reference Manual
Micromachine		Interdata 29-021, Model 3 Micro-programming Reference Manual
Technical Manuals		Interdata 29-026, Model 3 Digital System Maintenance Manual, Vol. I - Text
		Interdata 29-027, Model 3 Digital System Maintenance Manual, Vol. II - Drawings

DISPLAY PANEL

This device (Figure 3) is used by the computer operator to control the operation of the central computer. A more conventional name might be the "operator's console". It consists of a set of control switches, data (bit) switches, and lights.

Since the display panel is an Input/Output device, and is programmable at both the micro and conventional programming levels, the meanings of the lights and the interpretation of the switches is a function of the operating programs.

Device Number	1
Photograph	Figure 3
Speed	Data transfer involves no delay except for instruction execution time
Size	19" W x 14" H x 2" D
References	
Program Manual	Interdata 29-010, Display Panel Programming Manual
	Section III, below

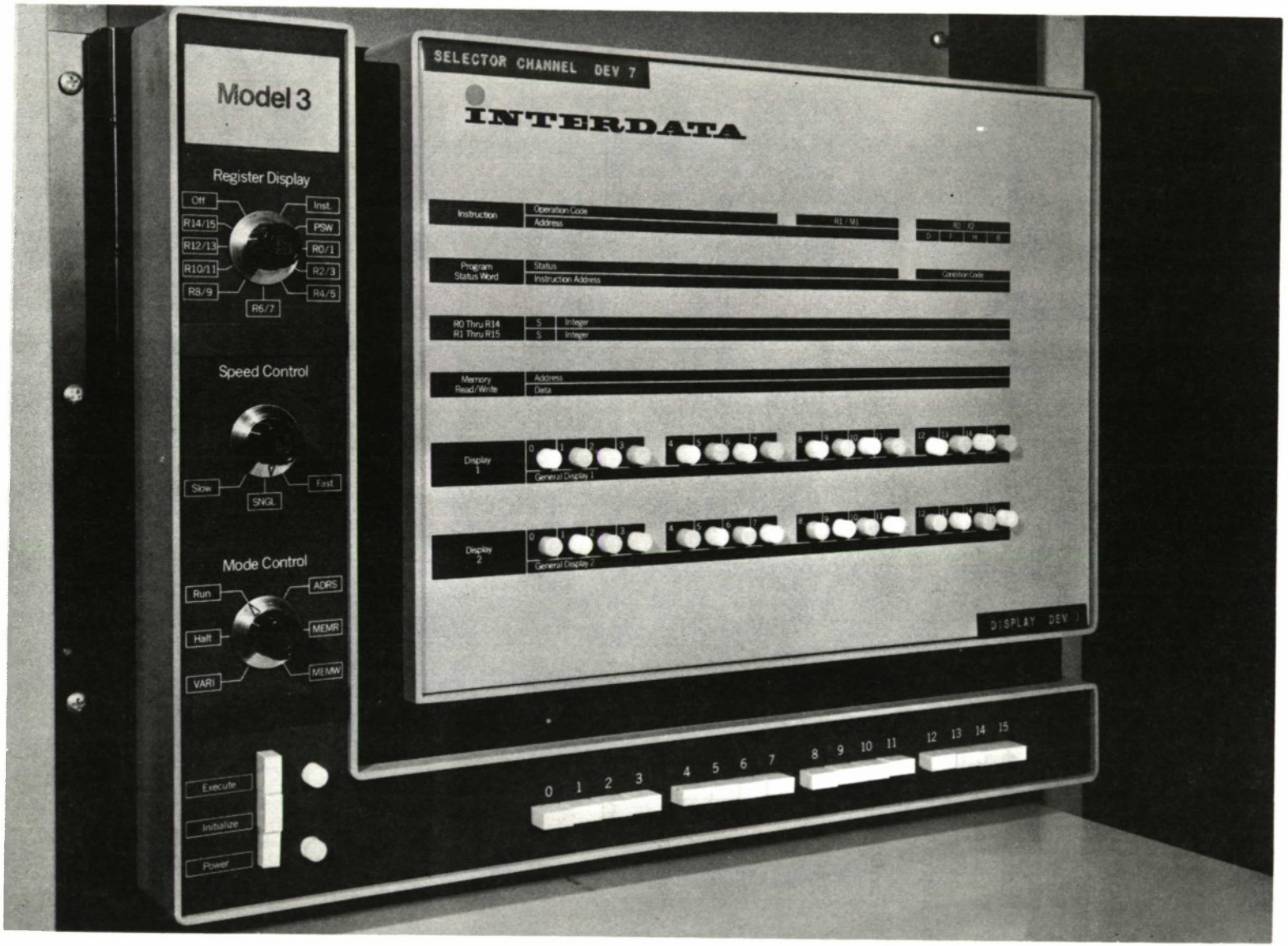

Figure 3. Display Panel

TELETYPE - MODEL 35 ASR

The Model 35 ASR teletype (Figure 4) provides a standard ASCII character set (upper case only) on a keyboard plus an 8-level paper tape reader and punch. This teletype, located near the central processor, is used primarily by the computer operator to control system operation.

Device Number	2
Photograph	Figure 4
Speed	10 characters per second
Code	8 level, 11.0 unit basis ASCII
Tape	8 level, 1-inch wide
Copy	72 characters/line, sprocket-feed platen, 8½" wide, 10 characters/inch, 6 lines/inch
Size	40" W x 38½" H x 24" D
Weight	225 pounds (approx.)
Power	115V ± 10%, 60 ± .5 cps
References	
Brochure	Teletype, Teletype Model 35 Equipment
Manual	Teletype, Bulletin 280B, Vol. I and II, Technical Manual Model 35 Automatic Send-Receive Teletypewriter Set (ASR)

Figure 4. Teletype – Model 35 ASR

TELETYPE - MODEL 33 ASR

These teletypes provide user interfaces to the I-3. They use a standard, upper-case only ASCII character set to communicate with the I-3, using a keyboard and an 8-level paper tape reader and punch.

Device Number	3, E
Speed	6-10 characters per second
Code	8 level, 11.0 unit basis ASCII
Tape	8 level, 1-inch wide
Copy	72 characters/line, sprocket-feed platen, 10 characters/inch, 6 lines/inch
Size	22" W x 33" H x 18½" D
Weight	56 pounds
Power	115V ± 10%, 60 ± .45 cps, single phase synchronous

References

Brochure	Teletype Corp., Teletype Model 33 Equipment
Program Manual	Interdata 29-011, ASR-33 Teletype Operation and Programming Manual

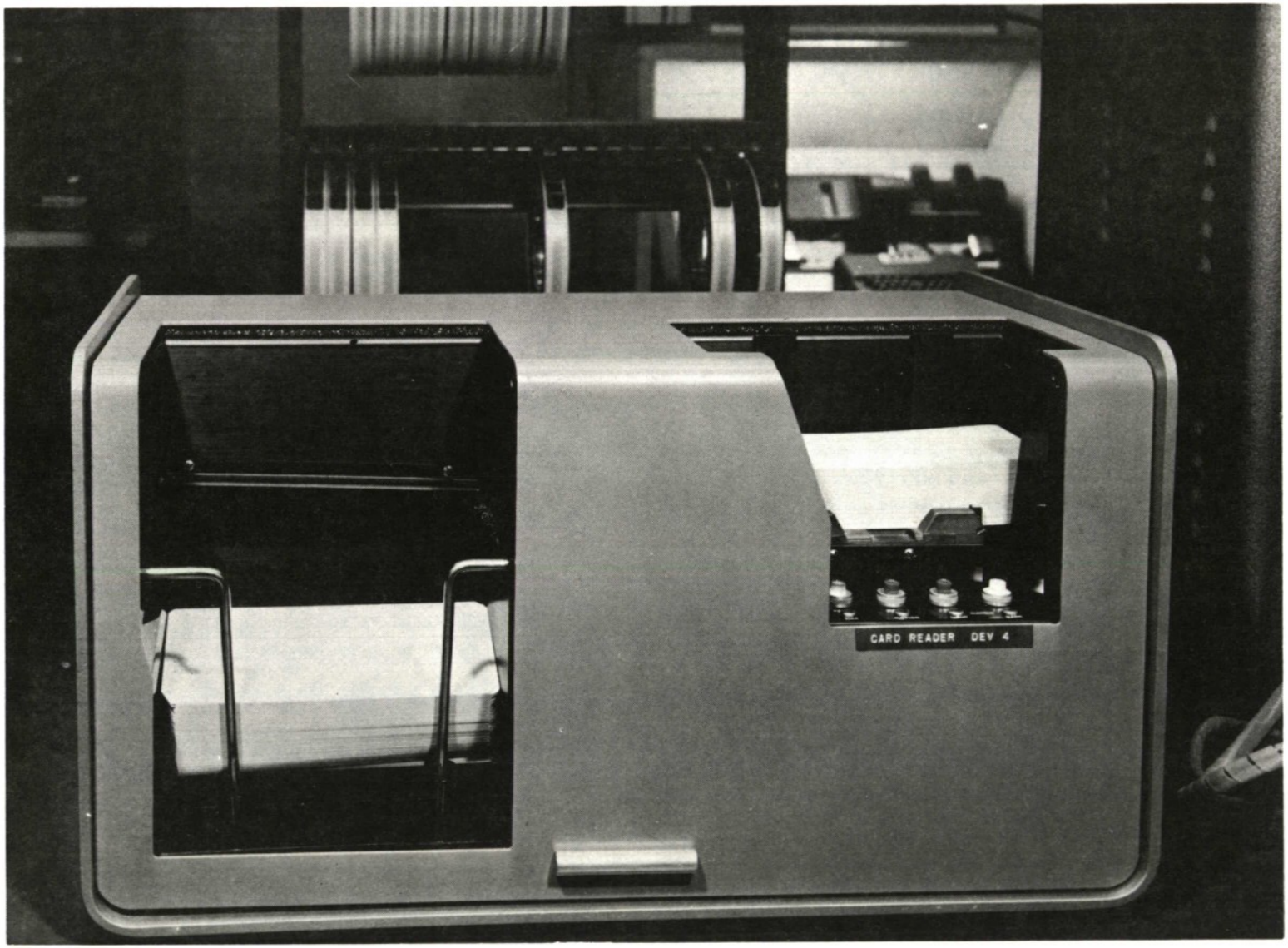

Figure 5. Soroban Card Reader

SOROBAN CARD READER

The Soroban card reader (Figure 5) reads standard, 80 column cards at a rate of up to 250 cards per minute using vacuum feed and photosensing.

Device Number	4
Photograph	Figure 5
Speed	225 cpm maximum; picks on demand at any rate
Hopper capacity	500 cards/hopper replenishable during operation
Code	Hollerith
Cards	Standard 80 column
Size	23" W x 12½" H x 12½" D
Weight	75 pounds (approx.)
Power	115V ± 10V, 60 ± 3 cps
References	
Brochure	Soroban, Super Compact Card Reader
Technical Manual	Soroban, Technical Manual, Soroban Compact Card Reader (SCCR)
Program Manual	Interdata 29-008RØ2, Card Reader Operation and Programming Manual

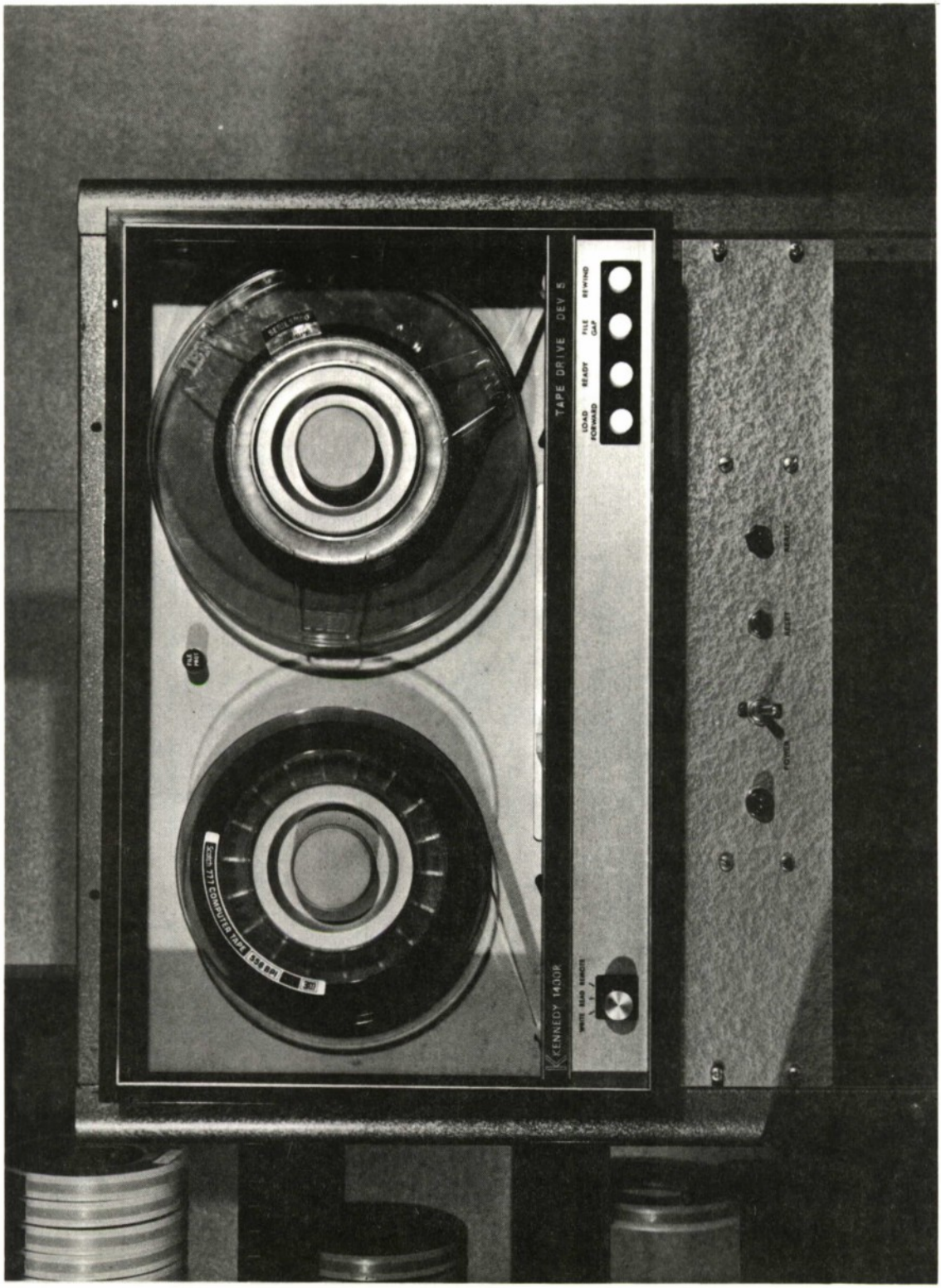

Figure 6. Kennedy Magnetic Tape, Model 1400 RH

KENNEDY MAGNETIC TAPE, MODEL 1400 RH (Figure 6)

This drive reads and writes standard magnetic tape in 9 track mode at 200 bpi density.

Device Number	5
Photograph	Figure 6
Speed	5 inches per second (1 KC)
Capacity - Reel	1200' by ½" by 1.5 mil computer tape on a 7" reel
Data	2,880,000 9 bit (8 plus parity) characters per 1200' reel
Mode	NRZI, 200 bpi, 9 track, internally generated odd vertical and even longitudinal parity
Gaps	3/4" record, 3.5" file, both on command
Size	19" W x 12¼" H x 12" D
Weight	50 pounds
Power	115V, 50/60 cps
Reference	
Technical Manual	Kennedy, Magnetic Recorder, Operation and Maintenance Manual Model 1400 Incremental

DATA DISC

The disc provides the I-3 with half a million bytes of fast access, on-line storage.

Device Number		6
Speed	Avg. Access Time	16.7 ms
	Rotation	1800 RPM + 1.3%, - 3.0%
	Data Rate	3.0 megabits per second + 1.3%, - 3.0% (62.5 KC)
Capacity		6.4×10^6 bits on 64 tracks or 6.4 million bits (524,288 bytes)
Addressing		By block, 128 characters/block
Size		19" W x 8 3/4" H x 19 3/4" D
Weight		62 pounds
Power		120V $\pm$ 10%, 60 + 0.5, - 1.5 cps, single phase, 8 amp starting current, 1.6 amp running current
References		
	Brochure	Data Disc Inc., F Series Fixed Head Disc Memory Systems
	Interface	Data Disc Inc., F Series Disc Memory, Input/Output Manual
	Technical Manual	Data Disc Inc., F Series Disc Memory, Electronics Manual
	Program Manual	Interdata 29-053, Data Disc Operation and Programming Manual

SELECTOR CHANNEL

The Selector Channel provides a high speed path from fast devices like the disc to the central computer. The Selector Channel controls the input/output operation by itself, stealing memory cycles when it needs them, which allows the central processor to operate concurrently.

Device Number	7
Speed	Maximum 500 K bytes/second
Reference	
Program Manual	Interdata 29-036, Selector Channel Programming Manual

CLOCK

The clock provides timing data for the central processor. It can be read at any time, providing an 8-bit value which is stepped every 100 μsec. Whenever the 8 bits overflow, every 25.6 msec, an interrupt occurs.

Device Number	8
Speed	Clock read is immediate; no input/output delay occurs

Figure 7. ARDS (Advanced Remote Display Station)

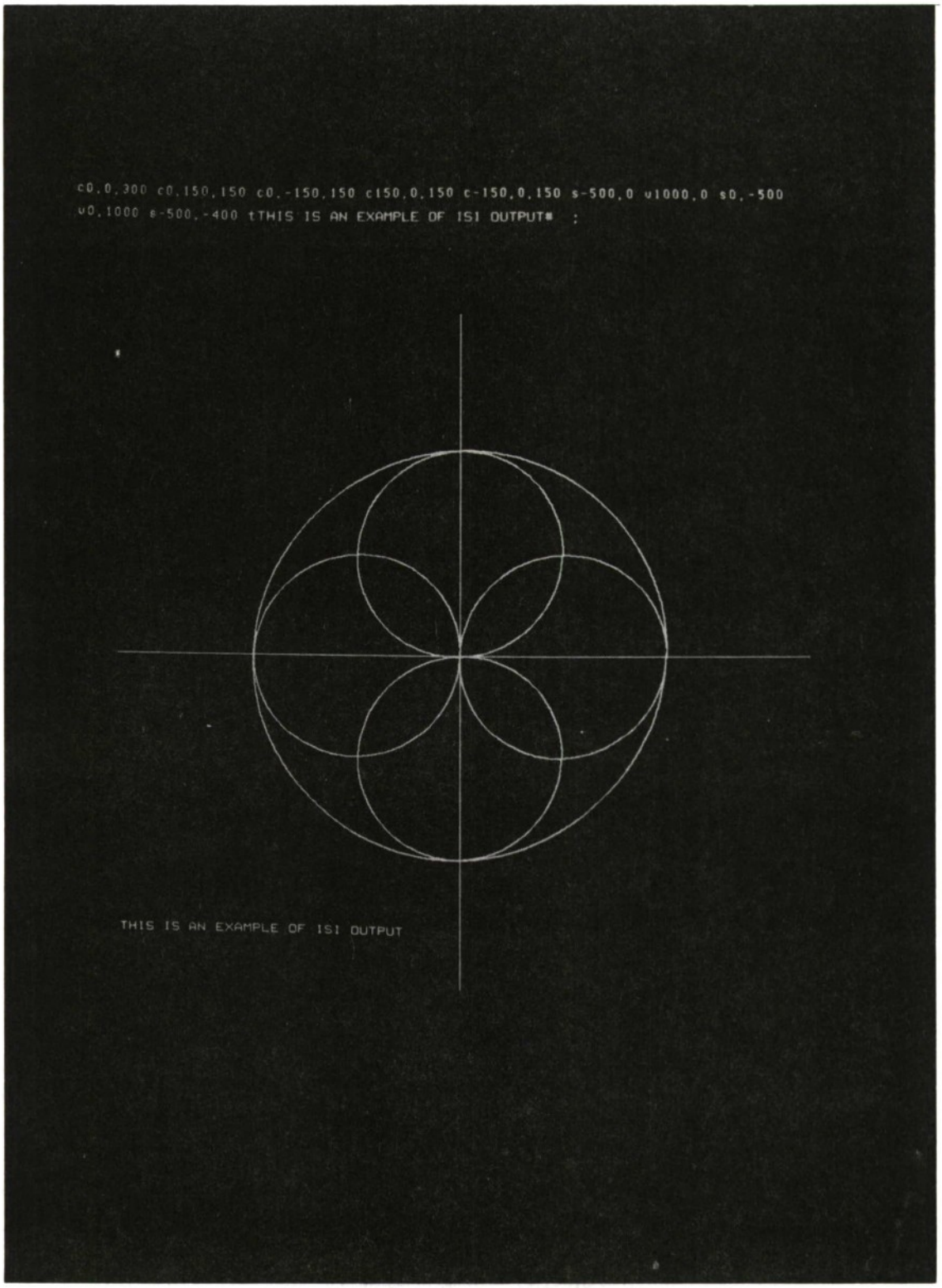

Figure 8. ARDS Display Sample

ARDS (ADVANCED REMOTE DISPLAY STATION)

The ARDS (Figure 7) provides displays of complex graphics (Figure 8) as well as alphanumerics. A keyboard allows entry of data in the 94 character ASCII set onto the storage display tube. The tube, which stores the image on the screen itself, need not be refreshed to retain the image; in fact, it must explicitly be cleared to remove old data.

A "mouse" allows a user to move the cursor about the display tube by moving the mouse and pushing one of three buttons to set a point, draw a line, and terminate.

In alphanumeric mode, 4000 characters (80 per line, 50 lines) can be displayed. In graphic mode, in a 6½" by 8¼" area, 1081 by 1415 addressable points can appear.

Device Number	A
Photographs	Figures 7, 8
Speed	2.4 msec/character (.416 KC)
Display Area	6½" by 8¼", 1081 by 1415 addressable points
Spot Size	8 mils nominal (adjacent addressable points overlap)
Stability	Stored data is absolutely stable
Storage Time	>15 minutes
Erase Time	500 ms (.5 second)
Contrast Ratio	3:1 or greater
Stored Luminance	At least 3 foot lamberts
Phosphor	P1
Point Addressing	Sign, magnitude with absolute coordinate 0,0 at the center of the screen

Vector Format	Sign, magnitude relative vectors; ΔX (change in X), ΔY (change in Y) component lengths are 0 to 1023 increments long
Keyboard	58 keys (capable of transmitting the 94 character ASCII set) with teletype capability and compatibility
Screen Symbol Capacity	80 symbols per line x 50 lines = 4000 characters, adjustable
Size	20" W x 19 3/4" H x 32 3/4" D
Weight	120 pounds
Power	115V, 60 cycles, 5 amps, single phase
References	
Brochure	Computer Displays Inc., Advanced Remote Display Station
Reference Manual	Computer Displays Inc., RM 86802, Advanced Remote Display Station Reference Manual

MOTOROLA 4300 PRINTER

This printer (Figure 9) is currently the fastest printed output device available on MITRE's I-3. Data is printed in 80 character lines of 10 point type on continuous form, friction feed, specially prepared current sensitive paper.

Device Number		D
Photograph		Figure 9
Speed		300 characters per second
Copy		80 characters per 7.2 inch line spaced 5 lines per inch; 6 x 7 dot matrix (5 x 7 per character + 1 column for spacing)
Paper		350', 8½" wide rolls of current sensitive paper; the last 20 ± 1 feet of the roll contains a red warning strip
Input Code		7 bit parallel code
Character Codes		66 character ASCII (CR - LF = one character)
Size	Printer	16" W x 9 1/2" H x 13 7/8" D
	Translator	17 1/2" W x 5 3/4" H x 7 1/2" D
Weight	Printer	40 pounds
	Translator	17 pounds
Power	Printer	115V ± 10%, 60 ± 2 cps; single phase; 115 watts
	Translator	115V ± 10%, 60 ± 2 cps; single phase; 57.5 watts

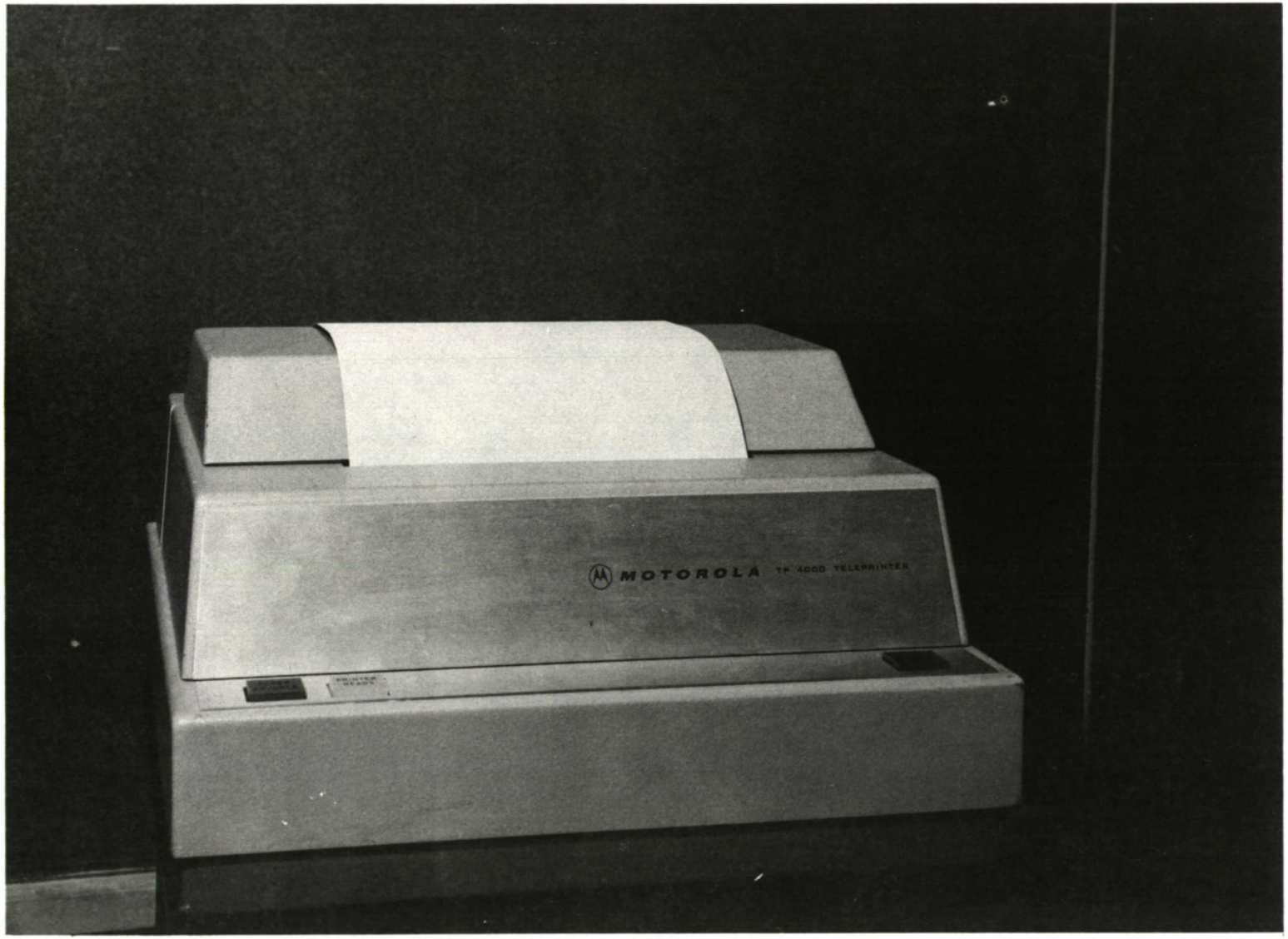

Figure 9. Motorola 4300 Printer

References

Brochure	Motorola's Silent, Desk Top, Non-impact, All Electronic, Low-cost Teleprinter - Half Size and Full Sound
Specification	Motorola, Inc., Specification for Motorola's TP4000 Series High Speed Teleprinter
Technical Manual	Motorola, Inc., 68P85900C11, TP4000 Series Teleprinter Technical Manual, Model 4300

SECTION III

FIRMWARE

GENERAL

The Interdata-delivered I-3 comes equipped with a read-only memory (ROM) which defines the instruction set of the standard I-3. This ROM, locally named "Primeval" is described in detail in Interdata 29-004, Reference Manual.

Another ROM, called the X-ray ROM, is provided by Interdata This ROM consists of a set of diagnostic microprograms designed to exercise the processor, core memory and the peripherals. The description and flow chart of this ROM appears in Interdata 3-109 X-3, Mod 3 X-Rays, while the listing is in Interdata 05-006A10, Mod 3 X-Ray Listing.

As a first attempt at microprogramming, a new ROM called "Calliope" was designed and built. In addition to the standard I-3 instruction set, which it executes more quickly and using less ROM space than in Primeval, Calliope contains code to implement an I/O channel, a set of program loading code (BOOTS) and a completely revised handling of the general purpose display panel.

CHANNEL

Calliope provides the user with an input/output (I/O) channel which may be used to perform input/output operations, using count-controlled, chainable commands to provide a large measure of program independent block transfer capability.

Operations on a device are initiated with a new instruction, start I/O channel (SIO), which identifies the device and points to the first of a series of I/O commands. Once initiated, the I/O will proceed independently under control of the chain of commands and a Device Status Word (DSW) table.

In addition to the standard I/O control operations, and the basic block transfer capability operating under count control, any subset of the 128 ASCII characters can be recognized (on input) in a special way, such that they may be omitted and/or may be used to terminate the operation.

BOOTS

BOOTS is a simple microprogrammed core loader for the I-3. BOOTS is capable of loading either punched paper tape from the teletype or cards from the card reader. It will perform scatter-loads to any part of real memory, including the "lower registers", e.g., the PSW. A continuous display of the address currently being loaded and the loaded contents thereof is generated.

Software programs to produce paper tapes (see PUSS, below) and cards (BOOTRAN) in the proper format have been developed.

DISPLAY PANEL

The Display Panel, as implemented in Calliope, is basically the same as supplied by the manufacturer, with some additions:

1. The new bootstrap microprogram (BOOTS, above) can be accessed, with the device to bootstrap from in the data switches.

2. A heretofore unused switch position, now labeled "MEMA" can be used to examine (MEMR) or modify (MEMW) storage without affecting the current location counter.

3. All sixteen data switches (instead of just the last eight) can be read under program control.

4. All thirty-two data display lights (instead of just the last eight) can be written under program control.

SECTION IV

SOFTWARE

SUMMARY

Most of the software currently available on the I-3 is that supplied by the manufacturer. This material falls into two broad classes, having to do with firmware or software. The MITRE produced software, so far, falls into the utility category.

Firmware Support

In support of firmware program production, Interdata supplies:

1. An assembler for assembling microprograms. It has been modified to accept card instead of paper tape input, and to print the output listing on the Motorola printer.

2. A simulator (ALICE) on which to try out programs assembled using the assembler.

3. A program (ROMWATS) to generate a paper tape suitable for wiring a microprogram. ROMWATS is, in fact, not delivered. It is used by Interdata to convert output tapes generated by the assembler or the simulator.

Descriptions of all these programs are contained in Interdata 29-021, Model 3 Microprogramming Reference Manual.

Software Oriented - Interdata Supplied

1. Assembler
2. Loaders
3. Fortran
4. Editor
5. Club (debug program)
6. Math Library
7. Test programs

Most of these features are described in detail in Interdata 29-013, Programming Manual.

Additional references include:

29-082, Editor (Tide) Program Manual

06-038A12, Card Reader Test Program Operation Manual

29-033R01, Mark III Memory Test Program Operation Manual

MITRE Software

1. PUSS
2. MI-3
3. Multiply-Divide
4. RGC Puncher/Loader
5. Card to paper tape
6. Tape Editor

PUSS

PUSS is a stand-alone utility for punching paper tapes on the I-3 teletype in a format suitable for loading with BOOTS, the (absolute) Bootstrap loader (see above, Section III, Boots). PUSS is self-relocating and has facilities for copying itself to any location in core. It can be used to generate individual records for a scatter-load, or it can generate a single data record and a PSW load record at one time.

MI-3

MI-3 is a machine language assembler to handle I-3 machine language. It is intended to fulfill two purposes which could not be achieved with the standard, manufacturer supplied assembler:

1. It provides the ability to define new instructions, a necessity where microprogramming continually changes the instruction set.

2. It is designed to run as fast as possible. First, it operates as a one pass assembler, with the assembled code placed directly in core. It may also produce a binary tape, but it runs concurrently with its input/output. Further, this output can be suppressed. Since it will accept input from the card reader instead of the teletype, it can attain optimum card reader speed. This means MI-3 can be used as an efficient assembler or a fast loader.

MULTIPLY/DIVIDE

Since the hardware/firmware multiply/divide is not available on the MITRE I-3, the multiply/divide program supplies this capability in response to the illegal instruction interrupt. It has been used in connection with MI-3, FORTRAN and some software associated with the ADS display.

RGC PUNCHER/LOADER

The RGC Puncher/Loader are two programs which allow punching of selected portions of core memory to paper tape, and the later reloading of the paper tape back into the original memory locations.

CARD TO PAPER TAPE

The card to paper tape program accepts a deck of punched cards as input and prints and/or punches a paper tape in one of two formats. In either mode, records punched on paper tape are variable length, with trailing blanks suppressed. In 80 column mode, up to 80 columns may be punched, and cards on tape are separated by LF-CR and six rubout characters. In 72 column mode, columns 73-80 are ignored, and no rubout characters are inserted between cards. If printing is used in 80 column mode, and non-blank characters appear in columns 73-80, they will all be printed in column 72.

TAPE EDITOR

The tape editor allows a user at the operator's teletype station to correct and repunch a source program paper tape. The program reads the paper tape, either operating one line at a time, allowing corrections from the teletype, or continuous feed, which can be interrupted for occasional changes.

APPENDIX

BIBLIOGRAPHY OF NON-MITRE DOCUMENTS

GENERAL

Data Processing Magazine, February 1968, P. J. L. Wallis, Auerbach Info, Inc.		The Interdata Series
Interdata	Brochure	Digital Systems, Model 2, Model 3, Model 4
Interdata	29-004	Reference Manual
Interdata	29-003R01	Systems Interface Manual
Interdata	29-005	Logic Module Handbook
Interdata	38-007	Data Communications
Interdata	38-029	Data Communications Systems
Teletype, Inc.	Brochure	Teletype Model 35 Equipment
Teletype, Inc.	Brochure	Teletype Model 33 Equipment
Soroban	Brochure	Super Compact Card Reader
Data Disc	Brochure	F Series Fixed Head Disc Memory Systems
Data Disc	Interface Manual	F Series Disc Memory, Input/ Output Manual
Computer Displays Inc.	Brochure	Advanced Remote Display Station
Computer Displays Inc.	RM 86802	Advanced Remote Display Station Reference Manual
Motorola, Inc.	Specification	Specification for Motorola's TP4000 Series High Speed Teleprinter

Motorola, Inc.	Brochure	Motorola's Silent, Desk Top, Non-Impact, All Electronic, Low-Cost Teleprinter - Half-Size and Full Sound

TECHNICAL MANUALS

Interdata	29-026	Model 3 Digital System Maintenance Manual, Vol. I - Text
Interdata	29-027	Model 3 Digital System Maintenance Manual, Vol. II - Drawings
Teletype, Inc.	Bulletin 280B	Vol. I and II, Technical Manual Model 35 Automatic Send-Receive Teletypewriter Set (ASR)
Soroban		Technical Manual Soroban Compact Card Reader (SCCR)
Kennedy Company	Technical Manual	Operation and Maintenance Manual, Model 1400 Incremental Magnetic Recorder
Data Disc		F Series Disc Memory, Electronics Manual
Motorola	68P85900C11	TP4000 Series Teleprinter Technical Manual, Model 4300

PROGRAMMING

Interdata	29-013R02	Programming Manual

includes

Interdata	TP111-7-8	General Description

Device Descriptions

Interdata	29-011	ASR-33 Teletype Operation and Programming
Interdata	29-010	Display Panel Programming

Interdata	29-008RØ2	Card Reader Programming Manual
Interdata	29-016	High Speed Paper Tape Reader Operation and Programming
Interdata	29-015	Auto Load Micro-Program
Loaders		
Interdata	06-025A12	Loader Descriptions
Interdata	06-030A12	Bootstrap Programs and Procedures
Assembler		
Interdata	03-001R01A12	Assembler Manual
Interdata	03-001M10R01A12	Operating Instructions for the TAPE Assembler and the CARD Assembler
FORTRAN		
Interdata	29-014	User's Manual for Interactive FORTRAN
Interdata	03-005R01A16	Operating Instructions for FORTRAN
Editor		
Interdata	06-008R01A12	Source Tape Preparator Descriptions
Debug		
Interdata	03-002R01A12	Hexadecimal Debug Program Description (CLUB)
Interdata	03-002R01	Relative Listing of CLUB w/output
Math Library		
Interdata	29-007	Math Library Abstracts and Descriptions
Test Programs		
Interdata	06-004A12	ASR-33 and ASR-35 Teletypewriter Test Program Operating Instructions
Interdata		Teletypewriter Test Program Listing

Interdata	06-003R01A12	Mark II Memory Test Description
Interdata	06-005R01A12	Model 3 Test Program Description
Interdata	29-053	Data Disc Operation and Programming Manual
Interdata	29-036	Selector Channel Programming Manual
Interdata	29-082	Editor (TIDE) Program Manual
Interdata	06-038A12	Card Reader Test Program Operation Manual
Interdata	29-033R01	Mark III Memory Test Program Operation Manual

MICROPROGRAMMING

Interdata	29-021	Model 3 Micro-Programming Reference Manual

includes

Interdata	TP107-5-8	Introduction to Micro-Programming
Interdata	TP108-5-8	The Micro-Programmed Processor
Interdata	29-017R01	Micro-Instruction Reference Manual
Interdata	05-010A12	Micro-Instruction Assembler
Interdata	TP109-5-8	Micro-Assembler Operations Manual
Interdata	05-011A12	Micro-Simulator (ALICE) Reference and Operator's Manual
Interdata	TP110-5-8	ROMWATS Description

SYSTEM CHECKOUT

Interdata	30-254-3	Interdata System Test Set Operation
Interdata	30-254-1	System Test Set, Figure 1 & 2

Interdata	28-001R01B08	Schematic System Test Set
Interdata	35-102R02B03	Assembly, Printed Circuit Test Set
Interdata	3-109-3-3	Mod 3 X-Rays
Interdata	05-006A13	Mod 3 X-Ray Listing

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13. ABSTRACT

The microprogramming facility at MITRE is designed to develop and explore the technology in the relatively new field of microprogramming.

This document describes the facility.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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